ARTIFICIAL ILLUMINATION.

BY

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BY L. A. W. ALLEMAN, A.M., M.D.,

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In the complex structure of modern civilization, builded by discovery, invention and adaptation, one upon the other, and mutually dependent and necessary, artificial illumination stands as a part of the very foundation.

It is imperative, under present conditions, that the working day should suffer no interruption, and this demand has been met by a multitude of devices for the production of light, which are marvels of convenience and economy.

When we consider the wonderful progress in this branch of the useful arts, and the incalculable economic value of these added working hours, it may seem unreasonable to criticise our present methods of lighting. A comparison of the tallow dip of our fathers with the modern searchlight should perhaps abash the critic and would assuredly do so, did we not take a broad view of the field and observe that progress has been along but one line, *viz.*, the production of candle power. We have striven to produce light, and we have made a most noteworthy success of it, but the hygienic quality of the light produced, its location and

distribution, are matters which have received no serious consideration.

It is difficult to understand why this eminently practical age should have thus recklessly endangered one of its most valuable assets, for I believe, despite the habitual disregard of all rules of hygiene in the care of the eyes, men in general do hold the preservation of vision as one of the really important considerations of this life; how, then, can we explain the fact that, in the matter of artificial illumination, we have made much less progress than in the field of general hygiene?

To answer this question we must glance at the history of the development of artificial lighting.

It is but a comparatively short time since the introduction of modern methods of interior illumination. Gas has come into general use within the last half century, and electricity is of very recent date. As has been pointed out by Birchmore,* the first use of gas for house lighting was in the ball-rooms of great houses, and the most convenient way to install this new light in an old house was to run the piping under the floor of the room above and drop a chandelier from the center of the ceiling. As the light was a novelty and an evidence of wealth and magnificence, this served the double purpose of convenience and display. The fashion was at once taken up by the would-be grand, and new houses were equipped with gas after the model of the grand establishment.†

There was, of course, no desire to hide this light under a bushel. It was put where it would be most in evidence, and it is an interesting question, as suggested by Dr. Birchmore, whether our modern high ceilings have not been determined by a desire to provide a suitable location for the pendant chandelier.

Starting thus as a fad of fashion, the obstrusive chandelier, stuck directly in front of our eyes, where it occasions the maximum of discomfort and the minimum of convenience, has fastened itself upon us. With different light sources it has undergone adaptation, but seldom improvement. It is sometimes made less objectionable in appearance, when not in action, but its modifications offer us at best but varieties in our annoyance.

We grow accustomed, however, to habitual discomforts and seldom realize how much of a nuisance this perversion of illumina-

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* *American Gas-Light Journal*, Nov. 29, 1897.

† Birchmore cites some curious old advertisements of "New Houses which are lighted exactly as that of Lord X———'s country house, etc."

tion is, until we are shown the contrast offered by a proper location and protection of the light source.

It is by no means in house-lighting alone that we suffer from improper illumination. Street and show-window lighting are barbarous in the extreme. No one will for a moment dispute the proposition that the desired object of the expenditure is to make objects visible, yet what is actually done is to exhibit light. The rational supposition is that the merchant wishes to attract the passer-by to the display in his window. What does he do? He hangs several arc lights before the window, just above the eye line, and sticks a multitude of clear glass incandescent globes or a row of incandescent burners on the inside. The result is

Showing light conservation by the use of reflectors—

From Cohn—

Light source 15 normal candle flame—

Metres aside from flame	0	0.5	1	1.50	2
With no shade—	1	3	4	2	1
With lacquered shade—	9	9	6	2	1
With polished shade—	64	15	6	2	1

Use metre tubing flame.

CHART I.

that all one sees in passing is a confused mass of light, and unless particularly interested in finding something no one will take a second look, and even should he do so the chances are that the dark spots and horseshoes projected upon any object at which he looks will prevent his seeing and appreciating the display. The merchant may be indifferent to the fact that these dark spots are foci of retinal exhaustion, "burned out holes," as it were, in our eyes, but it would seem evident to any rational being that, were these lights shielded by reflectors, thus shutting off the direct rays from the eyes of the shoppers, and directing the light upon the exhibit, a much more effective display would be obtained and the bill of lighting reduced from one-half to two-thirds.

The value of reflectors in conserving and rendering effective light units seems to be little understood and appreciated, as will

be seen from the subjoined table from Cohn (see Chart I.); their use is equivalent to an enormous multiplication of the light units, and the disregard of this fact by shrewd money-making tradesmen shows how deep is the ignorance of the first principles of correct lighting.

Street lighting is, I confess, a difficult problem and one which has as yet found no entirely satisfactory solution.

The present methods are, however, about as bad as they can possibly be made. Lights of very high candle-power and of great concentration are largely used. No attempt is made to shield the luminous point from the eye, and the lights are frequently hung in such a position that one cannot avoid looking distinctly at them.

I quite agree with Dr. Standish* that "it is a most outrageous thing that we should permit in our streets these electric arc lights to be hung almost directly in front of the eyes of the people as they walk along. When they are put upon a high pole, twenty to thirty feet above the ground, it is not so bad; but when you come to place them in front of a shop window, not more than three or four feet above your head as you walk along, I say that it is an injury to everybody that walks upon the street at night."

The unprotected arc light, particularly when elevated but slightly above the eye line, is a public nuisance which should be abated by the Board of Health.

Yet the electric arc light could undoubtedly be made one of the most valuable agents in street lighting by the employment of some simple device for shading and diffusion. Economy will always be the determining factor in street lighting, but better location, shielding and diffusion can all be obtained by municipal ordinance, and should be a matter within the province of the Health Board.

The illuminants† at our command are oil, gas, incandescent gas, incandescent and arc electric light, acetylene, and possibly, in the near future, Tesla's tubes.

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* Myles Standish, M.D., "On Light," *International Dental Journal*, June, 1896.

† Since the presentation of this paper, the increased use of *Incandescent Gasoline* entitles it to a place among the possibly available light sources. The simple gasoline flame needs to be mentioned, only to be condemned, but the incandescent burner should produce, with gasoline, a light having the same qualities as incandescent gas, and available in localities where illuminating gas is not attainable.

Incandescent Petroleum (Dudley, *Progressive Age*, Dec. 1, '97), is also in use as a high candle-power light source and should by adaptation be made available for house lighting and for portable lamps. Its great economy recommends it, and the light is of good quality.

The following table, which gives the comparative commercial cost of various illuminants, is taken from *Progressive Age,* Dec., 1897, and has been amplified by Mr. Dudley:

TABLE OF COMPARATIVE COST OF COMMERCIAL LIGHTING.

Number of Light Sources.	Number of Light Sources.	System of Lighting.	C.-P. per Standard Unit.	Total C.-P. of all Light.	Assumed cost, and consumption, rate per Unit.	Cost @ 10 Hrs. @ Unit.	Cost @1000 C.-P. Hrs.	Cost per Candle-Power per Hour.
1		Electric Arc-Light.	1000	1000	$80. @ Yr. of 3250 Hrs. @ 446 Watts.	$ .25		
	63	Incandescent Electric.	16	1000	$ .01 @ Hr. @ 55 Watts.		$6.25	$ .0006250
1		Incandescent Electric.	16	16	$ .01 @ Hr. @ 55 Watts.	.10		
	63	Illuminating-Gas jets.	16	1000	$1.25 @ 1000 cu. ft. @ 5 cu. ft. @ Hr.		3.92	.0003920
		Illuminating-Gas jets.	16	16	$1.25 @ 1000 cu. ft. @ 5 cu. ft. @ Hr.	.063		
	63	Illuminating-Gasoline jets.	16	1000	$ .50 @ 1000 cu. ft. @ 8 cu. ft. @ Hr.		2.50	.0002500
1		"Petrol-Arc" Light.	1000	1000	$ .07 @ Gal @ ¾ Gal. @ Hr.	..053		
	40	Acetylene-Gas jets.	25	1000	$10 @ 1000 cu. ft. @½ cu. ft. @ Hr.		2.00	.0002000
1		Acetylene-Gas jets.	25	25	$10. @ 1000 cu. ft. @ ½ cu. ft. @ Hr.	.05		
	16	Incandescent Ill'g-Gas lights.	64	1000	$1.25 @ 1000 cu.ft. @ 3 cu. ft. @ Hr.		.58	.0000575
1		Illuminating-Gasoline jets.	16	16	$ .50 @ 1000 cu. ft. @ 8 cu. ft. @ Hr.	.04		
	50	Center-draft Kerosene lamps.	20	1000	$ .07 @ Gal. @ 1-80 Gal. @ Hr.		.44	.0000438
1		Incandescent Ill'g-Gas lights.	64	64	$1.25 @ 1000 cu. ft. @ 3 cu. ft. @ Hr.	.038		
	16	Incandescent Illuminating-Gasoline lights.	64	1000	$ .50 @ 1000 cu. ft. @ 5 cu. ft. @ Hr.		.39	.0000387
1		Center-draft Kerosene lamp.	20	20	$ .07 @ Gal. @ 1-80 Gal. @ Hr.	.009		
	1	Electric Arc-Light.	1000	1000	$80. @ Yr. of 3250 Hrs. @ 446 Watts.		.25	.0000246
1		Incandescent Illuminating-Gasoline light.	64	64	$ .50 @ 1000 cu. ft. @ 5 cu. ft. @ Hr.	.003		
	1	"Petrol-Arc" Light.	1000	1000	$ .07 @ Gal. @ ¾ Gal. @ Hr.		.05	.0000053

It is impossible here to enter into a detailed consideration and comparison of the various light sources. No one is preëminently adapted to all situations or fulfils all the requirements of cost, brilliancy, steadiness and quality. Yet each has some special ad-

vantage, and a selection must be made in any case after a consideration of all the requirements.

Many of the evils of artificial illumination from which we are now suffering are common to all light sources; they are not inherent defects, but are faults of application; these we will touch upon later. We will first consider some of the good and bad features of the various light sources in common use.

The electric arc light has little to commend it save its brilliancy, and is the most objectionable illuminant in use. The electric arc presents a luminous point, from which is emitted an enormous candle-power; this concentration produces the maximum contrast effect when the light falls upon the retina, and a sharply defined area of retinal exhaustion. If, after looking at an arc light, or, for that matter, at a clear glass Edison globe, the eyes are closed for a moment one will see an image of the light as a dark spot before the eyes, which persists for some time, and after passing through a variety of colors fades away. This means that at the spot upon which this concentrated ray has fallen the delicate and complicated photo-chemical processes which have to do with vision have been interfered with. It is the same phenomenon as that observed after looking at the sun with the unprotected eye, and is attended with serious danger to the choroid and retina. Beside this, we meet clinically with the condition called by the French *L'ophthalmie electrique,* due to the exposure of the eye to the arc light, which is characterized by more or less pronounced conjunctival and corneal irritation. The patient complains of the sensation of a foreign body in the eyes, pain in eyes and head, photophobia and lachrymation. In many plants, when such exposure is necessary, the use of the protecting glasses (preferably dark gray*) is compulsory. This clinical picture is also produced by the exposure of the eyes to the sun's rays under certain conditions, by lightning flash, and by the Roentgen-ray. Chalupecky,† in considering this subject, calls to mind the investigations of Wedmark, who showed that these symptoms were not produced in like degree by exposure to all the rays of the spectrum, but were chiefly chargeable to the ultra-violet. The arc light, he contended, rich in the short waves, produces the symptoms, and the immunity obtained by protecting glasses is due to its relative impenetrability. Lightning is also rich in short waves and produces similar ocular disturbance, while the cataract

* Ljubinski, *Archives of Ophthalmology*, vol. 19, p. 349.

† *Centralblatt f. Augenheilkunde*, Aug. and Sept., 1897.

previously ascribed to the cramp of the ciliary muscle is attributed by Wedmark to the action of the light upon the lens, by which the ultra-violet rays are absorbed and transformed.

Sunlight, which is ordinarily poorer in the short waves, in a high altitude with low temperature (as for example, in the Arctic region) becomes richer; while reflection from the finely powdered snow still farther increases their relative preponderance.

Under these conditions snow-blindness is produced with symptoms similar to those just cited. Wedmark also notes the similar effect upon the skin produced by exposure to different light sources, and believes the so-called "Erythema Solare," and the dermatitis found among those exposed to electric light, and after lightning stroke, to be identical in origin. Chalupecky also cites Ogneff, who reproduced with animals the condition under which some people are obliged to work, and by exposure of the eyes to a powerful electric light produced conjunctival inflammation and corneal ulceration.

Accepting, then, the short wave as the causative factor in the production of the nutritive disturbance, Chalupecky proceeds to show the similarity in the action of the Roentgen ray, a very short wave length ray, both on the eye and skin. He produced in animals a similar inflammation and destruction of the anterior portion of the eye, and demonstrated its extreme danger and the fact that its effect is cumulative.

These experiments have, I think, been sufficient to convince us that the arc light, when unprotected, is unsafe, and to suggest that any light source rich in short wave length rays is probably dangerous.

The coal-oil lamp has much to recommend it, particularly as a reading light. Its portability insures the greatest advantage of position for the particular work upon which one may be engaged, and it readily lends itself to reasonable treatment by shades. The light is steady and the color fairly good. The heat and vitiation of the atmosphere are objections; but, generally speaking, the student's lamp is the best, always obtainable, cheap, and convenient reading light at our command.

The open gas flame, of whatever kind, should never be tolerated for interior illumination. The constantly varying gas pressure and the air currents make it flickering and unsteady.

The argand or round burner is somewhat better, but is far from satisfactory in quality and steadiness; pressure regulators, either at the meter or in the burner itself, are largely used and

result in some improvement, but the simple, flat flame and round burners should be replaced by more economical and satisfactory burners. The regenerative burner,* particularly in the form of a ventilating light, recommends itself to me, and can, I believe, be made applicable to the incandescent burner.

In this class of burners the heat of the flame is used to raise the temperature of the gas before ignition, which should make for economy, and another important end is subserved by utilizing the burner as a part of a ventilating system. It is placed high in the room, and a flue is led off from above the burner, by which not only the products of combustion of the flame itself, but also the superheated and vitiated air of the room is pumped out. This, of course, requires special construction, but in new houses both the artistic and sanitary requirements could in this way be satisfactorily met.

Wherever gas is used, the most satisfactory method of its employment is by the *incandescent burner* which is popularly known as the Welsbach or Auer light, from Carl Auer von Welsbach, who first introduced a cone or mantle made incandescent with a Bunsen flame. Many modifications of this burner are in use, but they are similar in principle. The chief recommendations of incandescent gas as a light source are its economy, steadiness and quality. In comparison with the ordinary flat burner we should get eight times as much light for our expenditure, as the light is due to incandescence and not to the flame, irregularities in gas pressure are largely taken up by the burner, while the more perfect combustion gives greater cleanliness. The quality of the light is variable and is largely dependent on the mantle. We can all remember the ghastly color of the first Welsbach lights, and if we notice a half dozen windows in succession thus lighted we will observe even now wide differences in quality. This difference is due to the proportion of the rare minerals put into the mantles.

For example, cerium raises the candle-power, and varying effects are produced by the interaction of the vibrations produced by different combinations of the ingredients. The age of the mantles, too, affects the light-giving qualities. Wherever these lights are in use they should be regularly inspected by some competent person to see that the drafts are not dust-choked, the mantles perfect and not smoked, and, in short, the burner kept at its full efficiency. When this is done, the economy effected by

* "Gas burners, etc.," Gerhard, 1894.

its use will enable us to obtain with it the proper quality of light, by shades and reflectors, with very little if any excess of cost over our present methods of lighting.

Incandescent electricity is, in some instances, a good light source. It should never, as I have previously shown, be used in such a way that the carbon filament is exposed to the eye. In most locations it gives a fairly steady light, but it is relatively expensive. Its chief virtues are that it consumes no oxygen and gives very little heat. For indirect lighting from a cove and domed ceiling its use is imperative.

*Acetylene** is a light source with which we are destined to become more familiar should it ever be allowed a fair competition on its merits. It should be one of the least expensive of all light producers. It can be made perfectly safe, despite the outcry against its danger, and is a light of superior quality. It is said† to give the nearest approach of any artificial illuminant to true sunlight color values, which would highly recommend it in industrial plants and shops where the colors are important. It is a highly concentrated light, and should, on this account, never be used save with proper diffusion.

Vacuum tube lighting is one of the startling promises which Tesla has given to the world, but it is as yet impossible to say whether or not it will become a commercial possibility. The fairy glow lamps are said to be very decorative, and the idea is certainly an attractive one. I have never seen the light, but I am inclined to question its desirability as a light source without material modifications. It probably runs too much to the short-wave end of the spectrum to be hygienic. An interesting personal experience of lighting by Tesla's tubes is given in a paper by F. N. Morton.‡ He says: I went to see the chapel, and found that, as far as the color was concerned, the light did very closely resemble daylight, although it had a bluish tinge. There was but little shadow cast, as was claimed by the inventor, Dr. Moore, who first attempted any lighting on a considerable scale by this method. This absence of shadows, however, was due purely and solely to the placing and position of the illuminated tubes in the room so that the shadow cast by one light was illuminated by a number of others, and not at all to the light from this source being able to deviate from a straight line and curl

* See "Lighting by Acetylene," Gibbs, Nostrand Co., N. Y., 1898.

† *Wochenschrift für Therapie und Hygiene des Auges.* Nov. 24, 1898.

‡ Morton. "Another View of Interior Illumination," Am. Gas Light Assn., 27th Annual Meeting.

around behind an obstructing medium. As far as the quality of the light is concerned, I have no hesitation in saying that the light was most trying to the eyes. I remained in the room for ten or fifteen minutes, and even for that short time could feel the fatiguing effect; and when I closed my eyes I could see every tube almost as distinctly as when looking directly at them, showing complete exhaustion of the retinal purple, and consequent injury to the eyes. An hour after leaving the building my wife, who was with me, said that her eyes were just recovering from the effects of the light in the chapel, and the next day she complained of discomfort, which she attributed to the same cause. There was a slight, continual shimmer or vibration in the light, but the same is more or less true of the arc light, and I hardly think it sufficient to account for the distress caused by this method of lighting. What improvement may be made in the future I do not know; but at present the method of lighting by Crooke's tubes cannot be said to be a success as far as being an agreeable or restful light is concerned."

There are certain general principles as to the location and diffusion of light which are of the utmost importance, whatever light source is employed in interior illumination.

The ideal condition, the normal illumination which we should endeavor to imitate, is the daylight condition, which is one of nearly perfect diffusion.* The source of light is not visible to the eye. The light, diffused by clouds, is admitted through the windows and is still farther diffused by all objects in the room which it illuminates. The light is nearly equal in all parts of a properly lighted room, and yet the slight variation in reflection gives the faint shadows which are so important in an estimate of form and perspective. Now how near do we approach this ideal in our every-day experience? We suspend just above the eye line small, intensely luminous points which are visible from all parts of the room and which must of necessity produce foci of retinal exhaustion. From the chandelier, the light radiates into the room with no attempt at diffusion and with an intensity diminishing according to the law of inverse squares as we approach the objects which we desire to illuminate (see Chart II.). Here again we are exhibiting light. Surely, were we endeavoring to render objects visible by illumination we would not put a blinding light directly in front of the eyes, at a point where nothing is to be seen, and

*Sufficient and properly located, unobstructed window spaces are of course presupposed, to obtain these conditions.

in a position where it will give the least illumination to our household gods, which we, presumably, wish to display.

Theoretically, no object in a room thus lighted is ever seen in the true proportion, save in a very limited area directly under the chandelier; practically this does not obtain, some diffusion is obtained under the present conditions, but the deep shadows and hard contrasts of one-sided lighting cannot but sacrifice much of the detail and proportion, and there is undoubtedly an enormous loss in artistic efficiency of our house furnishings entailed by this improper lighting. To a greater or less extent all objects are seen under a one-sided illumination, a graphic example of which is familiar to us all in flat flash-light photographs.

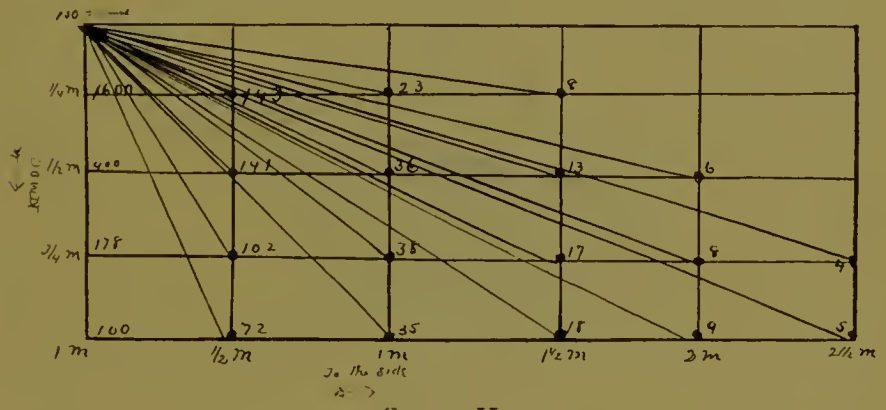

CHART II.

The whole problem, then, is one of approximating daylight conditions, and to this end there are two essentials. The concealing of the light source, and the diffusion obtained by making the walls, ceilings and furnishings all act as light distributors. This result is obtained by some modification of what is known as "indirect lighting." The first practical demonstration of indirect lighting with which I am familiar was made at the Paris Exposition in 1881, and it is now in use in several foreign schools, but has not been used to any considerable extent in this country. In its crudest form, indirect lighting may be obtained from any existing light source by placing underneath it an opaque reflector which shall conceal it at all points in the room below the eye line. From the upper part of the walls and ceiling the light is reflected and the modification thus obtained by the various reflecting surfaces do away with many of the objectionable features of the light source.

The first impression on entering a room thus lighted is that the illumination is insufficient, but this is due to the fact that one misses the accustomed glare and the hard shadows; but when objects in the room are looked at they are found surprisingly visible, and one is able to read with comfort in a room which seems at first but dimly lighted.

The quality of illumination is, of course, a separate problem and one to be determined in each room by its requirements, but it is, in any instance, only a matter of expenditure. This suggests a practical objection to indirect lighting, *i. e.*, the question of expense. In so vital a matter as the hygiene of the eye, I feel that it would be very poor economy to use improper lighting methods, even were the better methods relatively more expensive; but I do not believe that, in the main, indirect lighting will entail any additional cost. If a room is to be lighted at all, at least one light outlet must be used, of which the gas flame may be taken as a standard and as a minimum; for all purposes of general illumination this room can be properly lighted by the same gas flow by substituting for the open flame burner an incandescent burner and placing beneath it an opaque or translucent shade.

When a reading or working light is desired in any part of the room an individual light may be added for this purpose. This really involves no additional expenditure of light, for an individual reading light in addition to the general illumination is a hygienic necessity under present lighting methods. When it is desired to produce sufficient light for reading in all parts of a large room, as, for example, in a school-room, I should have been inclined to grant the necessity of a large expenditure, but the problem was carefully worked out by two German observers,* and the actual demonstration made that, by the substitution of incandescent for argand burners, proper lighting could be obtained at a reduced cost.

When recommending such a radical departure as a revolution in home lighting we have to combat the natural dislike for innovations, and at the same time be able to offer some desirable substitute for the shades and fixtures which have been brought to a high plane of artistic perfection. When we are given a new house in which to install a lighting system, the problem of combining hygienic lighting with artistic effect is much simplified. In some situations a domed ceiling and a deep cove with

* See *Progressive Age*, Feb. 1, 1898.

incandescent electric bulbs concealed in the cove give a very beautiful effect. But I do not consider indirect lighting from the ceiling as the best method either for effect or comfort. Side lights, with numerous outlets, and a consequent multiplication of the distributing centers should be sought, and on this account we require a smaller unit than that in common use. A twenty-five candle-power mantle or a ten candle-power electric could be used to better advantage. The side lights should be covered by reflectors which protect the eye from the light source and direct the light against the wall and ceiling. These reflectors may be made as elaborate and as artistic as desired, and can be more easily brought into harmony with the decorations and furnishing than can a central chandelier.

In dealing with old houses and attempting to adapt pre-

Fig. 1.

existing fixtures to the indirect system, the chief objection is the ugly effect of the reflector. I have made several experiments in this direction, and believe that such a remodeling can be effected in nearly every instance at a trifling expense and with satisfactory results both from an artistic and hygienic standpoint. I must admit that my first attempts with opaque shades were far from artistic, but by modifying my reflectors to harmonize with the fixtures, both ends were subserved. It is not necessary in all instances to use pure indirect lighting. For example, in a sitting-room 15x16 feet, with two side brackets, I have placed on one fixture, an inverted 10-inch shade of milk glass, which gives both direct and indirect light. The light source is so large that it is not unpleasant, and the room is sufficiently lighted for reading, by one burner. Again, in a room with a wrought-iron central chandelier wired for incandescent electric lights, I have

followed the lines of the chandelier in a reflector, blackened on the outside, which completely hides the light, and gives pure indirect lighting. (Fig. I.)

Fig. II.

For the dining-room I have made a reflector somewhat on the lines suggested to me by Mr. J. G. Dudley, *i. e.*, of making

Fig. III.

an artificial ceiling just above the burner. A cup is placed below the line of the mantle, and within curved and corrugated reflectors directed out and down catch the light from the inside of the

cup and at the same time from the inner surface reflect to the ceiling, and to the reflector above. (Fig. II.)

While this reflector does not give pure indirect lighting, yet it is very effective in light distribution, and seems well adapted, with modifications, to many situations. The next point to determine was whether its construction was feasible, commercially. I consulted the Mitchell Vance Company, who manufacture fixtures of all kinds, and they very kindly turned me over to their designer, Mr. R. V. Barrows, who undertook to design a shade on the lines which I suggested which would be equally pleasing to the eye when on and off duty. The result of his efforts is shown in Figs. III. and IV.

The outer surface of the lower ring is enameled in green, and the others in white. The lighting efficiency of the reflector is

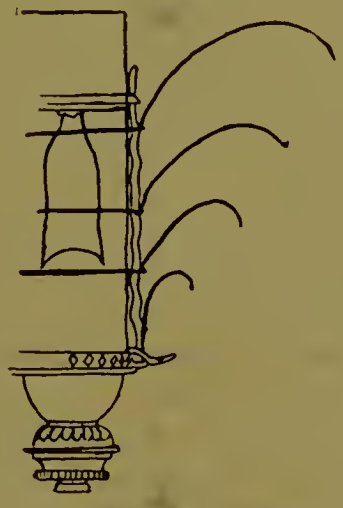

Fig. IV. section of shade.

surprising, and demonstrates the fact that a man who thoroughly understands his business can do better than an amateur. This reflector is, beyond doubt, more artistic than mine, and has the added advantage of being commercially obtainable, yet I cannot help regretting that Mr. Barrows could not have utilized the inverted cup at the base, as I believe it would have increased the available candle-power.

Next to the location and screening of the light source the tone of the decorations in a room is to be considered. We have practically no white reflecting surfaces, and in determining the light required in any given situation, we must take into account the great difference in the lighting value of different colors,* as well

* "Proceedings Am. Gas Light Assn." 1896.

as the relation between color of light source and reflecting surfaces. Any surface only gives back that portion of the light with which it is in harmony. To take an extreme example: If a room tinted a pure blue should be lighted with a red light, the room would be practically dark. It is, therefore, evident that the light source should be selected which most nearly approaches sunlight, both for the advantage in the amount of reflected light and to preserve in the room the greatest possible similarity in effect, under daylight and artificial lighting conditions.

This disregard of harmony is undoubtedly responsible for some of the ghastly lighting effects with which we meet and which we are unable at first to explain. Shades are often selected because they look desirable when seen on a lamp in the show room, or because, when a light is thrust into them by a salesman, the resultant tone is effective, but when they are put in place in the home, a blight seems to have fallen upon the family and its belongings. There is a sickly, unnatural look to everything, simply because the color of the shade is at war with its surroundings.

This subject is capable of almost indefinite expansion, but I have striven only to make it apparent that there is a wide field of usefulness open to that infant specialty, *viz.*, expert lighting.

The lighting engineer is as essential to a properly appointed house as is an architect; a layman knows absolutely nothing of these matters and very little has been written on the subject of hygienic lighting for his guidance; his only resource, therefore, is to call upon a scientifically trained engineer, not a man who has some particular method of lighting to exploit, who will come into his house and make a careful study of the situation there presented. Each house, each room is a special problem, and it is only by careful consideration of these conditions and of the habits and requirements of the individuals who are to use the light, that the best results can be obtained.

All new work should be so installed that the fundamental requirements are fulfilled, and the adaptation to the individual necessities should follow after the house is tenanted. It is not, however, always convenient to build new houses, and if ideal conditions are not obtainable we must not forget that in old houses, without structural changes, the lighting is capable of a most surprising improvement with a minimum outlay of time and money.

The one point which I had chiefly in mind when undertaking the preparation of this paper was the determination of the quality

of light best suited to the eye, and the elements which go to make up that proper quality.

I was much disappointed to find that little work had been reported in this most important field, and I endeavored to obtain, experimentally, some reliable data upon which to generalize, but the results were by no means satisfactory.

Experiments with retinal fatigue as a measure of the hygienic quality of light gave some promise, but the source of error in this, as in all other attempts, was the wide variation in results, which arose from individual peculiarities, and I have little expectation of arriving at any conclusions in this field which will be broadly applicable. The effect of any given light differs so much in each subject, and in the same subject is so modified by conditions which are not constant, that our ideal light quality must be subject to frequent revisions.

For example, with advancing age, certain changes take place in the crystalline lens—it grows smoky sooner or later; this interposes between the retina and the light source the equivalent of a smoked glass which filters out certain rays, thus altering the quality of the light.

Myopia is another modifying influence; the long eye of the myope does not focus the rays of light on the retina, and the varying refrangibility of the different rays which make up the light undoubtedly yield a varying resultant according to the refractive condition, from the same light source.

Again, a far-sighted eye does not receive the same rays with as without a correcting glass, and any pathological condition affecting the transparency or density of the media would introduce an additional source of error.

In conclusion, a suggestion as to the arrangement of a reading light.

When a room is sufficiently lighted by the indirect method, reading is possible in all parts of the room, but where this ideal condition is not obtainable the best arrangement for reading is an overhead light, preferably screened by a reflector underneath, and a desk or table light with an opaque shade which will protect the eyes and throw the light down upon the book.

It is a common error to read by a single light which is thrown upon the book while the room is in nearly total darkness. The brilliancy of the page is supposed to be all that is necessary. A

momentary consideration of a well-known fact of retinal physiology will show the reason for the discomfort thus occasioned.

Retinal sensibility increases rapidly in the dark; on entering a comparatively dark room nothing is seen, but in a moment objects begin to be visible. The sensibility increases most rapidly at the moment of entering the dark room, and proceeds more and more slowly until the limit of sensibility is reached.

When reading by a single light the room presents practically the dark-room condition; all the retina which does not receive the image of the paper is attuned to darkness. When we look up for a moment, the eye instantly makes the adjustment to the room lighting, and when the brilliant page is again looked at it is almost as dazzling as the sun, the contrast is so striking. No one would think of reading in the direct glare of sunlight. We all appreciate that diffused daylight is far preferable; yet from the frequency with which I find this condition reproduced by a reading light, the fallacy must be widely held, and I would lay especial stress upon this point. An insufficient reading light is less harmful than the extreme contrast of a too bright light in a dark room. If only one light can be had, it is better to use a translucent shade and let the light shine in the eyes; it will do less harm than the green reflector delusion.

With a proper quantity and location of light for reading the quality of the light must be determined by individual necessities. In practice, I advise those with sensitive eyes to procure a skeleton shade, and cover it experimentally with a succession of tissue papers in delicate tints, till the one is found which proves most acceptable, which is usually a yellow-green.

One of the most startling discoveries which the investigator makes in studying lighting is the wide and sudden variations in daylight illumination.* We are never subjected to such contrasts by any artificial system, they could not be tolerated. Yet we know by experience that the eye is indifferent to these changes, and that they produce no discomfort. The reason for this lies

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* Weber found by daily measurements the following variations in illumination by diffused daylight in summer and winter:

December	579 to 9863 m. c.
January	1592 to 13770 m. c.
June	4519 to 76560 m. c.
July	8414 to 69180 m. c.

Cohn found in four schools in Breslau the following variations in daylight illumination.

in the fact that full visual acuity is reached at 50 m.* candles, and after this point a very considerable increase in illumination has practically no effect on the eyes. This gives us a rough standard of sufficient illumination. As it is not always convenient to have at hand the elaborate instruments for determining candle-power, Cohn† has suggested that we have a fairly reliable photometer in the healthy human eye, and that the illumination by which such an eye can attain full visual acuity is a safe amount of lighting. Cohn considers 50 m.c. a full illumination, and 10 m.c. a minimum. In determining a proper standard of illumination we should always keep in mind that a meter candle has nothing to do with light *production*. In the table (Fig. I.) showing light gain by reflectors, we have but 1 m.c. at a point directly under the light, which is much less than the theoretical amount. The light was intercepted by the fixture, or what not. The only fact which concerns us is the light given back from the page at which we look. A room may have a theoretical excess of light, and by wall tones and improper arrangement of light source the illumination may still be insufficient. You may, then, be entirely indifferent to the number of candles your light gives if you find experimentally, by some delicate test, that you cannot increase your visual acuity by increasing the illumination. The fine crossed lines on process pictures, answer admirably for the test.

In diseases of the eye, as in general medicine, we look more to prevention than to cure, and, as in general disease, it is the bad habit that is most difficult to discover and remove. We can easily control patients when they are seriously alarmed, but it requires a large store of patience to demonstrate to the average

School.

	In brightest part of room.	*In darkest part of room.*
1 Clear	61 to 450 m. c.	1.7 to 32 m. c.
2	82 to 420 m. c.	1.8 to 68 m. c.
3 Day	189 to 1142 m. c.	7.9 to 133 m. c.
4	320 to 1410 m. c.	21 6 to 160 m. c.
1 Dull	4.7 to 235 m. c.	.1 to 22 m. c.
2	2.6 to 182 m. c.	.1 to 10 m. c.
3 Day	121 to 1052 m. c.	3.4 to 69 m. c.
4		4.6 to 38 m. c.

* A *meter candle* (Weber), which is the standard of measurement for illumination, is the luminosity of a piece of paper at one meter from a standard candle, measurements of illumination should be made by a Weber or some similar photometer which determines brightness not candle power, as does the ordinary bar photometer. For a description of the Weber photometer see *Progressive Age*, Dec. 1, 1897, or Cohn, *Lehr. Hyg. des Auges*, p. 852.

† Cohn, *Lehrbuch Hygiene des Auges.*

person that his pet system of lighting causes his asthenopia. I am more and more convinced, however, that a large part of the discomfort and a respectable proportion of the diseases of the eye with which we have to deal are due to improper illumination, and I make it a routine practice to inquire into the lighting conditions under which the eyes are used, with patients presenting unusual retinal sensibility.